# Improved Modeling for Water Surge Wave

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**Abstract- This work presents a computational model for surge wave in water transmission pipeline. The work also mentions to the roll of High Technology for water transmission pipeline control. The experimental results of laboratory model and the field test results showed the validity of prediction achieved by computational model. This work showed the effects of the penetrated air on the surge wave velocity in water pipeline. It revealed that "MOC" computational model is accurate model for investigation of surge wave. Hence in order to presentation for importance of penetrated air on water hammer phenomenon, it was compared the models for laboratory; computational and field tests experiments. As long as these procedure, it was showed that the Eulerian based model for water transmission line in comparison with the regression model.**

***Key words: water hammer; surge wave;*** high ***technology; regression; computational model.***

## I. INTRODUCTION

High Technology encompasses interactive computer-based applications that allow people to online control the complex technical plant. Hence it will provide the suitable way for solution of complex scientific and researches problem. Water hammer as a fluid dynamics phenomenon is an important case study for designer engineers. This phenomenon has a complex mathematical behavior. Today High Technology provides a suitable condition for finding new methods in order to reduction of water hammer disaster. Water hammer disaster can be happened at earthquake or tsunami. For example, at these critical conditions, water transmission pipeline control at power plants; water treatment plants; water transmission and distribution plants will be at high risk due to damage or failure hazard. As a side effect of water hammer phenomenon, this situation increases the probability of surge wave generation. Surge pressure and velocity of surge wave acts at fast transients, down to 5 milliseconds. So it must be detected on actual systems (by field tests) by High Technology and high speed detectors. Also, besides the flow and pressure, it must be computed by computational model. The recording of fast transients needs to use the high technology and online data intercommunication. This procedure produces a theoretical result that usually corresponds quite closely to actual system measurements based on Geography Information System "GIS". Water hammer is explained on the basis of compressibility of liquid.

Many researchers have made significant contributions in this area. N.E. Zhukovsky introduced the concept of the effective sound speed. He mentioned to reducing the motion of a compressible fluid in an elastic cylindrical pipe to the motion of a compressible fluid in a rigid pipe, but with a lower modulus of elasticity of the liquid. Subject of transients in liquids are still growing fast around the world. Scientists have developed various methods of investigation for transient pipe flow. These ranges of methods are included by approximate equations to numerical solutions of the nonlinear Navier–Stokes equations. They obtained the differential equations of motion

of inviscid fluid formed the basis for further development of the theory of pressure and pressure flow of viscous fluid. By helping of this theory, it became possible to explanation of the physical phenomenon, known as water hammer. They introduced the concept of the effective sound speed. Therefore transient flow was solved for the pipeline in the range of approximate equations. These approximate equations are solved by numerical solutions of the non-linear Navier–Stokes equations in a method of characteristics “MOC”.

Curve estimation for the experimental results of laboratory model and the field test results is the most appropriate when the relationship between the dependent variable and the independent variable is not necessarily linear. Linear regression is used to model the value of a dependent scale variable based on its linear relationship to one or more predictors.

Non-linear regression is appropriate when the relationship between the dependent and independent variables is not intrinsically linear. Binary logistic regression is most useful in modeling of the event probability for a categorical response variable with two outcomes. The auto-regression procedure is an extension of ordinary least-squares regression analysis specifically designed for time series. [1-3].

## II. MATERIALS & METHODS

Surge wave speed and water flow variation at water pipeline is affected by free water bubble. This work studies on this affection. A computational model for liquid- vapor flows illustrates the numerical techniques for solving the resulting equations. Hence field test model was chosen for experimental presentation of water hammer phenomenon at the water pipeline. Transient analysis results that are not comparable with actual system measurements are generally caused by inappropriate system data (especially boundary conditions) and inappropriate assumptions. In order to practical development for present work from a theoretical basis, comparisons between the models and validation data can be grouped into the following three categories:

(a) Cases for which closed-form analytical solutions exist given certain assumptions if the model can directly reproduce the solution, is considered valid for this case.

(b) Laboratory experiments with flow and pressure data records. The model is calibrated using one set of data and, without changing parameter values, it is used to match a different set of results. If successful, it is considered valid for these cases.

(c) Field tests on actual systems with flow and pressure data records.

These comparisons require threshold and span calibration of all sensor groups, multiple simultaneous datum, and time base checks and careful test planning and interpretation.

Present work investigated the validation data related to precision of measurement and calibration of all sensor groups. Although it defined the nonlinear heterogeneous model, and it predicted the air entrance or, air penetrated into the water pipeline .Hence the penetrated air built serious problem and error source for sensor groups' measurement. The maximum amount of infiltrated air at this work was mentioned in the result section.

$$\frac{dV}{dt}+\frac{1}{\rho}.\frac{\partial P}{\partial S}+g\frac{dZ}{dS}+\frac{f}{2D}V|V|=0\,, \tag{1}$$

(Euler equation)

$$C^2\frac{\partial V}{\partial S}+\frac{1}{\rho}.\frac{d\rho}{dt}=\circ\,, \tag{2}$$

(Continuity equation)

Partial differential equations (1, 2) are solved by method of characteristics "MOC" :

The method of characteristics is a finite difference technique which pressures were computed along the pipe for each time step. Calculation automatically sub-divided the pipe into sections (intervals) and selected a time interval for computations equations are the characteristic equations (3, 4).

$$\frac{dV}{dt}-\frac{g}{c}.\frac{dH}{dt}=\circ \quad \text{or}$$

$$dH=\left(\frac{C}{g}\right)dV\,, \tag{3}$$

(Zhukousky)

If the pressure at the inlet of the pipe and along its length is equal to $p_0$ , then slugging pressure undergoes a sharp increase:

$\Delta p : p = p_0 + \Delta p$ .

The Zhukousky formula is as flowing:

$$\Delta p = \left( \frac{C.\Delta V}{g} \right), \tag{4}$$

The speed of the shock wave is calculated by the formula equations (5):

$$C = \sqrt{\frac{g.\frac{E_W}{\rho}}{1 + \frac{d}{t_W} \cdot \frac{E_W}{E}}}, \tag{5}$$

For the velocity of surge or pressure wave in an elastic case with low value of free water bubble, the flowing equation (6) would be valid:

$$C = \frac{1}{\left[ \rho \left( \left( \frac{1}{E_W} \right) + \left( \frac{D}{E.t_W} \right) + \frac{n}{P} \right) \right]^{\frac{1}{2}}}, \tag{6}$$

The velocity of surge or pressure wave in an elastic case with the high value of free water bubble the flowing equation (7) would be valid [2-3]:

$$C = \left( \frac{g.h}{n} \right)^{1/2}, \tag{7}$$

The variables are as follows: $C$ —Velocity of surge wave $\left( m/s \right)$ as a dependent variable with nomenclature "*Y*", independent variable with nomenclature "*X*" such as: $n$ — Percent of air volume $\left( m^3 \right)$. The curve estimation procedure allows quick estimating regression statistics, and producing related plots for different models. Hence the auto-regression procedure by regression software "SPSS 10.0.5" was selected for the curve estimation procedure in the present work. The regression model has been built based on field test data.

Regression model is due to field test for surge wave velocity. Curve estimation is the most appropriate when the relationship between the dependent variable and the independent variable is not necessarily linear.

Linear regression is used to model the value of a dependent scale variable based on its linear relationship to one or more predictors.

Non-linear regression is appropriate when the relationship between the dependent and independent variables is not intrinsically linear. Binary logistic regression is most useful in modeling of the event probability for a categorical response variable with two outcomes.

The auto-regression procedure is an extension of ordinary least-squares regression analysis specifically designed for time series.

One of the assumptions underlying ordinary least-squares regression is the absence of auto-correlation in the model residuals. Time series, however, often exhibit first-order auto-correlation of the residuals. In the presence of auto-correlated residuals, the linear regression procedure gives inaccurate estimates of how much of the series variability is accounted for by the chosen predictors. This can adversely affect the choice of predictors, and hence the validity of the model. The auto-regression procedure accounts for first-order auto-correlated residuals. It provides reliable estimates of both goodness of-fit measures and significant levels of chosen predictor variables.

One of the approaches of this work was the definition of a model by regression. It was defined based on the relationship between the dependent and independent data or variables for surge wave. The curve estimation procedure allows quick estimating regression statistics, and producing related plots for different models. Hence the auto-regression procedure by regression software "SPSS 10.0.5" was selected for the curve estimation procedure in the present work. Therefore the regression model was built based on the field test data.

Regression software "SPSS" has fitted the function curve and provided regression analysis. So, the regression model has been found in the final procedure. By this model, field test results have been compared by computational model results. The main practical aim of the present work was concentrated on the definition of a condition base maintenance (CM) method for all water transmission systems. In this work the data collection procedures were as follows:

Curve estimation procedure is illustrated in Figure (1) and (2) for surge wave velocity was formed by estimating regression statistics are listed in Tables (1). Although related plots for the field test model were produced [4-8].

## III. RESULTS AND DISCUSSION

In this work conclusions were drawn on the basis of experiments and calculations for the pipeline with a local leak. Hence, the most important effects that were observed are as follows: The pressure wave speed generated by water hammer phenomenon was influenced by some additional factors. Therefore the ratio of local leakage and discharge from the leak location was mentioned.

The effect of total discharge from the pipeline and its effect on the values of wave oscillations period were studied. The outflow to the surge tank from the leak affected the value of wave celerity. The pipeline was equipped with the valve at the end of the main pipe, which was joined with the closure time register. The water hammer pressure characteristics were measured by extensometers.

TABLE I. Regression for model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .930(a) | 0.865 | 0.856 | 9.08222 |

a Predictors: (Constant), AIR VOLUME PERCENT

In Power functions is illustrated in Figure (3), however, a variable base is raised to a fixed exponent. The parameter $b_{\circ}$ serves as a simple scaling factor, moving the values of $X^{b_1}$ up or down as $b_{\circ}$ increases or decreases, respectively the parameter $b_1$, called either the exponent or the power, determines the function's rates of growth or decay [9-14].

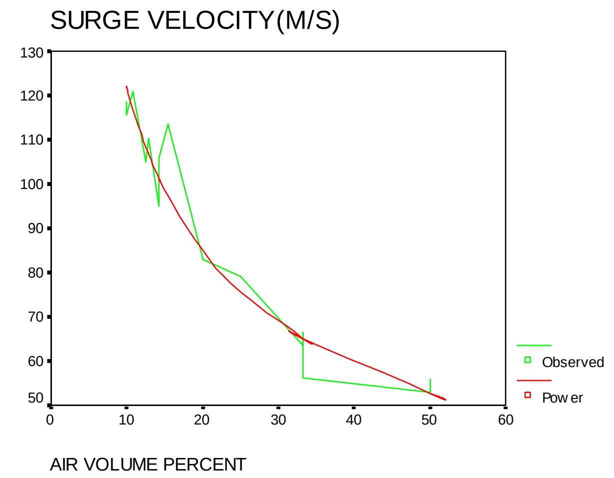


Figure 1. Power curve fit for surge wave speed of water pipeline with free water bubble

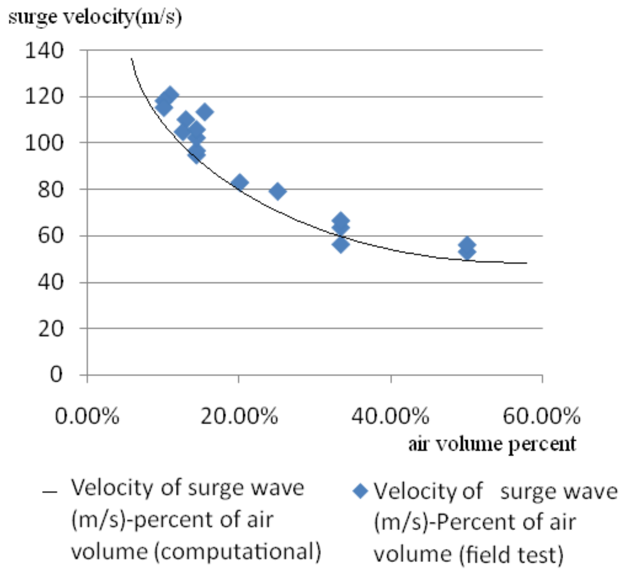


Figure 2. Regression for surge wave speed of water pipeline with free water bubble

*S. Pejovic, 1987*, Obtained flow variation for water pipeline with free water bubble which is illustrated in [14- 17]. Comparison showed similarity in present work and the results of that works.

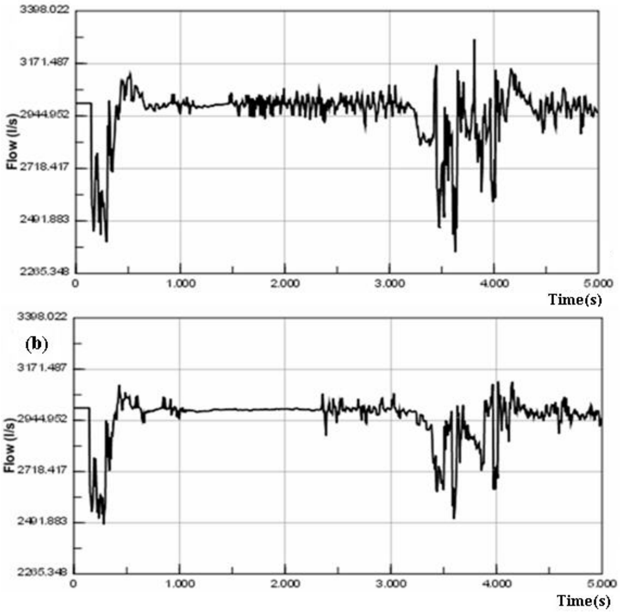


Figure 3. Flow histories for water pipeline; a) without free water bubble, b) with free water bubble

In this work conclusions were drawn on the basis of experiments and calculations for the pipeline with a local leak. Hence, the most important effects that were observed are as follows: The pressure wave speed generated by water hammer phenomenon was influenced by some additional factors.

Therefore the ratio of local leakage and discharge from the leak location was mentioned.

The effect of total discharge from the pipeline and its effect on the values of wave oscillations period were studied. The outflow to the surge tank from the leak affected the value of wave celerity. The pipeline was equipped with the valve at the end of the main pipe, which was joined with the closure time register. The water hammer pressure characteristics were measured by extensometers.

The supply of the water at the system was realized with the use of the reservoir which enabled inlet pressure stabilization. In this work, positive water hammer in the pipeline was introduced with local leaks in two scenarios; first; with the outflow from the leak to the overpressure reservoir, second; with free outflow from the leak to atmospheric pressure, with the possibility of sucking air in the negative phase. The bubbles in nonlinear dynamics fluid state acts as a separator gate for two distinct parts of the flow at upstream and downstream of separator gate. It causes high surge wave velocity at one of these distinct parts. Therefore the compressed air builds high pressure flow which can destroy the water pipeline.

The results are as following:

1. Numerical tests showed that the proposed second-order formulation at boundary conditions (achieved by using virtual cells) is second-order. In addition, the proposed formulation maintains the conservation property of FV schemes and introduced no unphysical perturbations into the computational domain.

2. Numerical tests were performed for smooth (i.e., flows that do not present discontinuities) and sharp transients.

3. The high efficiency of the proposed scheme was important for Real-Time Control RTC of water hammer flows in large networks.

In present work, changes at system boundaries (Sudden changes) created a transient pressure pulse. In this regard, model design needed to find the relation between many variables accordance to fluid transient. Therefore, a computational technique was presented and the results were compared by field tests. In present work after closing the valves on the horizontal pipe of constant diameter, which moves the liquid with an average speed $V_{\circ}$, a liquid layer, located directly at the gate, immediately stops. Then successively terminate movement of the liquid layers (turbulence, counter flows) to increase with time away from the gate. In this work the air was sucked into the pipeline. Pressure wave velocity was recorded in fast transient up to 5 milliseconds (in this work 1 second). The assessment procedure was used to analysis the collected data which were obtained at real system.

## IV. CONCLUSIONS

High Technology and high speed detectors were investigated as long as this work. By field tests on Actual system, this work focused on the effects of the penetrated air on the surge wave velocity in water pipeline. It showed that "MOC" computational model is accurate model for investigation of surge wave. Hence in order to presentation for importance of penetrated air on water hammer phenomenon, it was compared the models for laboratory; computational and field tests experiments. As long as these procedure, it was showed that the Eulerian based model for water transmission line in comparison with the regression model. On the other hand, this idea were included

the proper analysis to provide a dynamic response to the shortcomings of the system. It also performed the design protection equipments to manage the transition energy and determine the operational procedures to avoid transients. Consequently, the results of this work will help to reduce the risk of system damage or failure at the water pipeline.

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NOMENCLATURES

$C$ : Velocity of surge wave $\left(m/s\right)$

$n$ : Percent of air volume $\left(m^3\right)$

$t_W$ : Wall thickness of pipe $\left(mm\right)$

$g$ : Acceleration of gravity $\left(m/s^2\right)$

$h$ : Head of the liquid (water) column, $\left(m\right)$

$E$ : Modulus of elasticity for pipeline material Steel

$E = 10^{11}\left(Pa\right)$, $\left(kg/m^2\right)$

$d$ : Outer diameter of the pipe $\left(mm\right)$

$\rho$ : Density $\left(kg/m^3\right)$

$P$ : Surge pressure $\left(Pa\right)$

$E_W$ : Module of elasticity of water $\left(Pa\right)$

$t$ : Time $\left(S\right)$

$V$ : Velocity $\left(m/s\right)$

$S$ : Length $\left(m\right)$

$D$ : Diameter of each pipe $\left(mm\right)$

$Z$ : Elevation head $\left(m\right)$

$f$ : Darcy Wieshach coefficient

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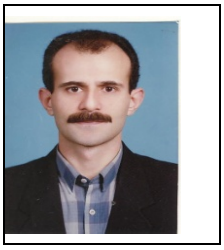
**BIOGRAPHIES**



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